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ABSTRACT

Science process skills include basic skills like observing, inferring, measuring, communicating, classifying, and predicting, as well as integrated skills like controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models. Recognition of the value of science process skills has resulted in the development of new instructional techniques and strategies. Some research suggests that computer-assisted instruction (CAI), in the form of self-instructional programs written for microcomputers, may be effective in teaching these skills. This study sought to develop a CAI module designed to improve the integrated science process skills of community college students, as measured by students' pre- and post-CAI scores on the Test of Integrated Process Skills (TIPS). Their scores on the Enhanced American College Testing Assessment (Enhanced ACT) were used as a balancing measure of academic aptitude. The CAI module, which during its development was also subject to formal evaluation by an expert review panel, included two tutorial programs and two laboratory simulations, and was examined in the study for ways in which it presented information, guided students through assimilation of new information, and provided practice to enhance understanding. The student sample consisted of 92 students enrolled in General Biology I for Science Majors (at a small, rural community college located in the southeastern United States), equally divided into a control group and an experimental group. The control group had the opportunity to use commercially produced tutorials designed only to improve knowledge of biology content, while the experimental group used the CAI module for improving integrated process skills. The study revealed no significant difference between the mean gains of the control group and the experimental group (0.05 to 0.07), although the experimental group did show a more marked improvement on the individual subtest involving graphing and data interpretation. Nor did the effectiveness of CAI seem to be influenced by a student's academic aptitude or gender. The study's results suggest that instructors should not expect noticeable improvement in students' integrated science process skills. Due to the small scale and time constraints of this study, findings should be considered with some caution. Seven tables illustrate the data. (Contains 41 references.) (BEW)

THE EFFECT OF COMPUTER-ASSISTED INSTRUCTION ON THE SCIENCE PROCESS SKILLS OF COMMUNITY COLLEGE STUDENTS

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INTRODUCTION

Science process skills are the skills used by scientists to study and investigate the world (Funk, 1985). Padilla (1986) classified science process skills into two major categories; basic science process skills and integrated science process skills. The six basic science process skills are: (a) observing, (b) inferring, (c) measuring, (d) communicating, (e) classifying, and (f) predicting. The integrated science process skills are: (a) controlling variables, (b) defining operationally, (c) formulating hypotheses, (d) interpreting data, (e) experimenting, and (f) formulating models.

Since 1967, when the American Association for the Advancement of Science (AAAS) advocated the teaching of science as a process (American Association for the Advancement of Science, 1967), the attention of science educators has been focused on improving the science process skills of students. The mastery of content material alone will not produce students capable of solving real world problems (Raths, Jonas, Rothstein, & Wassermann, 1967).

Strawitz (1989) describes the teaching of science process skills as "one of the major goals of teacher preparation programs" (p.659). Penick and Dunkhase (1988) describe the process of science as a common theme found in college science courses identified as exemplary by the Society of College Science Teachers. The recognition of the value of science process skills has resulted in the development of new instructional techniques and strategies designed to enhance the learning of these skills.

The literature contains a number of reports on the relative effectiveness of these new methods. Particularly interesting is the finding that students taught science process skills using self-instructional methods outperformed those taught by a teacher (Strawitz & Malone, 1987). Since computer-assisted instruction (CAI) has many of the characteristics of conventional programmed learning methods, this finding suggests that self-instructional programs written for microcomputers may be effective in teaching science process skills.

Statement of Problem and Hypotheses

In recent years, a considerable amount of research has been conducted on the effectiveness of computer-assisted instruction (CAI), especially at the elementary and secondary level. Much of this research has focused on the effect of CAI on academic achievement. A number of studies have compared CAI to traditional instructional methods in regard to academic achievement. The effect of CAI on critical thinking has received some attention, but the effect of CAI on integrated science process skills has been largely neglected.

The problem of this study was to develop a computer-assisted instructional module designed to improve the integrated science process skills of community college students. Additionally, the study sought to determine what effect the program had on students' integrated science process skills. This information can be used to guide the effective application of CAI at the community college level.

Four null hypotheses were tested.

H_1: There will be no significant difference (α=0.05) between the mean gain in integrated science process skills of those students who participate in the computer module and those students who do not participate in the computer module as measured by the students' total score on the Test of Integrated Process Skills (TIPS) (Dillashaw & Okey, 1980).

H_2: The mean gain scores on the TIPS subtests of students who participate in the computer module will not be significantly different (α=0.05) from those of students who do not participate in the computer module.

H_3: There will be no significant difference (α=0.05) between the TIPS mean gain scores of low and high academic aptitude students, as determined by the American College

Testing Program Assessment (ACT), following instruction with the computer module.

H_4: There will be no significant difference (α=0.05) between the mean gain scores of males and females on the TIPS following instruction with the computer module.

Rationale for Study

Ten years ago, Waugh (1985) called attention to the need for more research on the effect of computer-assisted instruction on students' science process skills. The need for that research is as pressing today as it was in 1985 as only one study specifically addressing the effect of computer-assisted instruction on college students' integrated science process skills was identified (Faryniarz & Lockwood, 1992). The study by Faryniarz and Lockwood (1992) suggests that CAI can be effective in the teaching of science process skills at the community college level. Faryniarz and Lockwood did not investigate the effect of academic aptitude and gender on the effectiveness of CAI. If CAI is to be used effectively in the community college, more research is needed.

Waugh and Currier (1986) suggest investigating the possible differential effects of CAI on high and low academic aptitude students. Some researchers (Jamison, Suppes & Well, 1974; Kulik, Kulik, & Cohen, 1980) have reported that academically disadvantaged students may profit more from CAI than their more academically talented peers. Hativa and Shorer (1989) reported that high-ability students benefit more from CAI. Miller (1993) reported finding no statistically significant evidence of a relationship between the effectiveness of CAI and student academic ability. The discrepancies in these findings suggest that the relationship between academic aptitude and the effectiveness of CAI is worthy of further research.

Waugh and Currier (1986) recommended additional research on the relationship between gender and the achievement of students taught using CAI. The discrepancies in the research findings in this area prompted Roblyer (1989) to recommend further research on the relationship between gender and the effectiveness of CAI. Some studies (Burns & Bozeman, 1981; Edwards, Norton, Taylor, Van Dusseldorp, & Weiss, 1974; Wooley, 1978) suggest that males profit more from CAI than females. Miller (1993) and Reagan (1992) reported finding no significant relationship between gender and the effectiveness of CAI.

Methods and Materials

Sample

The subjects involved in this study were students enrolled in General Biology I for Science Majors at a small, rural community college located in the southeastern United

States. Most of the students enrolled in General Biology are majoring in medicine (pre-nursing, pre-physical therapy, pre-medicine, etc.), forestry, agriculture, or biology; and intend to transfer to a university or professional school. The majority (≈90%) could be described as traditional college students in that almost all are full-time students and the mean age for the group is 18.6 years. The mean composite ACT score for the group was 18.9. The sample contained 92 students. Sixty-one students were female. Thirty-five students were male. The sample contained 36 black students and 56 white students.

Data Gathering Instruments

Science process skills were measured using the Test of Integrated Process Skills (TIPS) (Dillashaw & Okey, 1980) and the Test of Integrated Process Skills II (TIPS II) (Burns, Okey, & Wise, 1985). The TIPS is a 36 item, multiple-choice type test with four alternative answers for each question. Content validity was established by a panel of four science educators. The test reviewers and test developers agreed on the assignment of test items to objectives 95% of the time, and on test scoring 97% of the time. Field testing of the instrument with 7-12th grade students produced a reliability coefficient of 0.89 (Cronbach's alpha). The reliability coefficient is based on the proportion of error variance to total variance yielded by a measuring instrument (Kerlinger, 1986). A reliability coefficient of 1.0 would indicate perfect reliability. The reading level of the test is Grade 9.2.

The TIPS II (Burns, et al., 1985) is also a 36 item, multiple choice test. It was designed to measure the same process skills as the original TIPS test. The authors have reported a reliability coefficient of 0.86 (Cronbach's alpha). Content validity was established by a panel of six science educators. The test has a reported reading level of Grade 9.5.

The TIPS and the TIPS II are reported by the test authors to be equally difficult. The authors (Burns, et al., 1985) reported an average item difficulty index of 53% for both tests.

Both TIPS and TIPS II contain five subtests. Each of the subtests is designed to measure a specific integrated science process skill. Subtest 1 measures a student's ability to identify variables. A student's ability to identify and state hypotheses is measured by subtest 2. Subtest 3 measures a student's ability to operationally define terms. Subtest 4 measures a student's knowledge of investigation design. A student's ability to graph and interpret data is measured by subtest 5.

Academic aptitude was measured using the Enhanced American College Testing Assessment (Enhanced ACT) composite score. The ACT Assessment is a curriculum-based measurement of academic development in mathematics, English, reading and science reasoning. The American College Testing Service does not consider the Enhanced ACT an aptitude test, "but rather describes their test as an analytical, problem-solving test" (McManus, 1992, p. 6).

ACT scores are used by colleges as indicators of a student's potential for academic success. American College Testing Service claims that the Enhanced ACT Assessment provides an accurate measure of a student's ability to succeed at college-level work (McManus, 1992).

ACT scores do appear to be useful predictors of student performance. Noble and Sawyer (1989) reported that for 12 freshmen mathematics and English courses at 277 colleges; ACT scores were better predictors of student performance than high school grades.

Since a strong relationship between academic aptitude and academic performance would be expected, ACT scores should provide a useful measure of academic aptitude. O'Hearn (1984) describes the ACT subtests as measures of both aptitude and achievement. The suggestion that the ACT can be used as a measure of academic aptitude is supported by the correlation between ACT scores and Scholastic Aptitude Test (SAT) scores. The SAT, administered by the Educational Testing Service, is an aptitude test (McManus, 1992). College admissions officers regularly convert ACT and SAT scores using concordance tables. The interchangability of the scores suggests that both tests are measuring similar characteristics.

The Computer-Assisted Instructional Module

Introduction

The CAI module evaluated by this study was written by the researcher using the ACT III authoring software package (ACT III 2.5, 1991). The module consists of four programs. Two of the programs, Science Skills I and Science Skills II, are tutorials. The other programs, Investigating Photosynthesis and The Effect of pH on Enzyme Action, are laboratory simulations. The programs utilize text and animated color graphics. The software requires machines with an MS-DOS operating system, 640K of RAM, and a color graphics adapter (CGA) or higher video adapter. Each program requires approximately 45 minutes to complete.

Instructional Objectives

The overall instructional objective for the CAI module is to improve students' integrated science process skills. The five integrated process skills measured by the TIPS and TIPS II are; (a) graphing and interpreting data, (b) identifying variables, (c) identifying and stating hypotheses, (d) operationally defining, and

(e) designing investigations (Burns, et al., 1985; Dillashaw & Okey, 1980). The instructional objectives of the CAI programs were chosen to address these skills.

The programs were submitted to an expert review panel to determine if the programs adequately addressed the stated instructional objectives. All six members of the review panel were qualified to teach science, or computer science, at the college level. The reviewers' responses indicate that the panel agreed that the stated instructional objectives were covered by the CAI programs.

Software Design

The programs were designed using the criteria suggested by Alessi (1984). Alessi points out that effective instruction, regardless of delivery system (teacher, books, computers, etc.), has four major steps; (a) present the information, (b) guide the student in the initial acquisition of the new information, (c) provide practice to enhance understanding and retention, (d) assess achievement in order to guide remediation, or end instruction. Rarely does a single CAI program provide all four steps.

The CAI programs developed for this study contain the first three steps of the instructional process. The programs present new information, guide the student through the assimilation of this information, and provide practice using the new information. The programs do not assess the students' achievement. The TIPS II will be used for assessment.

Two of the programs written for the CAI module are tutorials; Science Skills I and Science Skills II. Alessi (1984) describes the six components of an effective CAI tutorial (see Figure 1).

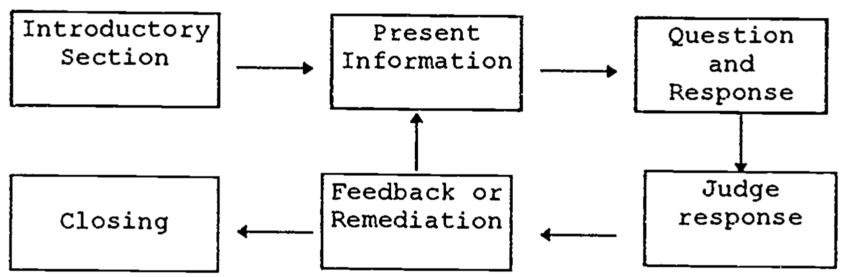

Figure 1. Components of a Tutorial (Alessi, 1984)

The introductory section consists of the title page, instructions, and objectives. The program then enters a cycle. The program presents information to the student, then quizzes the student on that new information. The student makes a response. The program analyzes the student's response and provides appropriate feedback. If the student has responded correctly, the program provides information to reinforce that behavior. If the response is incorrect, the program explains and describes the correct response. This immediate feedback should correct and prevent misconceptions. The cycle repeats until the lesson is finished. The tutorials in the CAI module are based on this six-part design.

The CAI module contains two simulations; Investigating Photosynthesis, and The Effect of pH on Enzyme Action. The simulations make use of the same six-part design used in the tutorials, but they also contain a sequence of screens that display a simulation of an experiment. The student conducts the experiment under different conditions and collects data on the dependent variable. The data is then used to construct a graph illustrating the relationship between the variables being studied.

Program Descriptions

The programs, Science Skills I, and Science Skills II are identical except for the questions that they ask. Both programs are divided into five parts. Each part covers a specific integrated science process skill. Part 1 explains the identification of variables. Hypothesis formulation is covered by Part 2. The concept of operationally defining terms is introduced by Part 3. Designing experiments and graphing data are explained by Parts 4 and 5, respectively.

The computer simulation, Investigating Photosynthesis is divided into two parts. The program begins with a tutorial describing factors affecting the rate of photosynthesis in plants. The tutorial section also discusses laboratory methodologies for investigating photosynthesis. The program concludes with a simulated experiment designed to investigate the effect of light intensity on rate of photosynthesis. The student changes the independent variable light intensity and gathers data that will be used to calculate the dependent variable, rate of photosynthesis. The student uses the data to construct a graph of the relationship between light intensity and rate of photosynthesis.

Part 1 of the program, The Effect of pH on Enzyme Action discusses enzymes and enzyme function. Part 2 introduces the student to laboratory techniques for studying enzymes. The third part simulates an experiment designed to study the effect of pH on an enzymatic reaction. The student conducts the experiment at three different pH's and collects data on the dependent variable, reaction rate. In Part 4, the student uses the collected data to construct a graph of the relationship between pH and reaction rate.

Program Evaluation

Hannafin and Peck (1988) explain the benefits of frequent evaluation on software development. The major goal of software evaluation is to; (a) determine if the lesson objectives are being met, (b) identify reasons for the observed performance, (c) identify those portions of the lesson were modification is necessary (Hannafin & Peck, 1988).

Early versions of the programs were informally evaluated by student volunteers. Students who were part of the study sample were not involved in these evaluations. The students were asked to work through the programs and make notes on the programs' ease of operation and educational quality. Students discovered a number of programming problems and typographical errors during these sessions. They also made important suggestions on improving the software design.

When the programs were near completion they were submitted to an expert review panel for formal evaluation. The review committee was composed of six science and computer science instructors with experience in CAI. Each committee member evaluated two programs. This provided three individual reviews of each program.

The members of the review committee were provided with: copies of the programs, instructions for operation of the programs, a list of instructional objectives for each program, and evaluation forms. The evaluation form contains 15 Likert-type items and space for additional comments. The items included on the evaluation form are modifications of items listed by Hannifin and Peck (1988). Eight of the items provide information on the instructional design of the software. The instructional clarity of the software is evaluated by four items. Ease of use, a component of instructional adequacy, is evaluated by a single item. The program adequacy and cosmetic adequacy of the software are each evaluated by a single item.

Reviewers' responses to the evaluation form were assigned values from one to four (Strongly Disagree=1, Strongly Agree=4). The mean response for each item was then calculated for the four programs. The results of the evaluation indicate that the programs have adequate designs.

An informal field test was used to further document the programs' coverage of the stated instructional objectives. A small number (N=26) of student volunteers participated in the field test. The students involved in the field test were not enrolled in General Biology and did not participate in any other phase of the study.

Two instruments were written by the researcher for use in the field test. Instrument A was based on the instructional objectives of the programs Science Process Skills I and Investigating Photosynthesis. Instrument B was based on the instructional objectives of the programs Science Process Skills II and The Effect of pH on Enzyme Action.

Students were administered either Instrument A, or B, as a pretest. The student then received instruction from the appropriate computer programs. After receiving instruction, the student was administered the same instrument as a posttest. A t test was used to analyze the data. Table 1 presents the results of this analysis. An examination of the means and the *t* values (see Table 1) indicates that the students, in both groups, scored significantly higher ($\alpha=0.05$, $p<.001$) on the posttest than on the pretest. This finding indicates that the computer programs do improve student performance on the stated instructional objectives. This finding supports the opinion of the expert review panel.

Table 1

Field Test Results

Instrument	Pretest Mean	Posttest Mean	*N*	*t*
A	9.2	12.8	12	5.92***
B	9.4	13.7	14	5.87***

Note. Maximum possible score 20.

***$p < 0.001$

Procedure

The experiment was conducted during the regularly scheduled General Biology laboratories. The laboratory sections meet once a week, in the afternoon, for three hours. All the laboratory sections were taught by the researcher. The experiment required two consecutive laboratory meetings of each section.

Six laboratory sections were involved in the study. The total sample size was 92 students; 46 students in the control group, and an equal number in the experimental group. Roscoe (1975) recommends a sample size of at least 50 in experimental research, but points out that in experimental designs with tight control sample sizes as small as 10-20 may produce useful results.

Table 2 summarizes the characteristics of the treatment and control groups. Additionally, Table 2 provides information on the total student population of the college. A *t* test indicated no significant difference (α=0.05, *p*=0.54) between the mean composite ACT scores of the treatment and control groups. This finding suggests that the two groups can be considered equal in academic aptitude.

Table 2

Summary of Sample Characteristics

Characteristic	Control	Treatment	College Population
N	46	46	656
Mean ACT[a]	18.6	19.1	18.6
Mean Age	20.7	19.3	19.3
Gender			
Male	14	17	337
Female	32	29	319
Race			
Black	22	14	269
White	24	32	387

Note. [a]Composite ACT Score.

Students were randomly selected within each section so that each section was equally represented in the treatment and control groups. This provided control for possible differences between sections. Approximately half of the students in each section were in the control group. The other half of that section was in the treatment group.

During the first of each sections' two meetings, the TIPS (Dillashaw & Okey, 1980) was administered to all the students in that section as a pretest. The students in each section were divided into treatment and control groups. Therefore, both groups received the test at the same time and under the same conditions.

After the pretest, the members of the control group completed the computer tutorials; Chemicals of Life I: The Structure of Matter ("Chemicals of Life I," 1985), and Chemicals of Life II: Water, Carbohydrates, and Lipids ("Chemicals of Life II," 1986). These commercially produced tutorials use text and animated graphics to introduce students to basic cell chemistry. These programs are designed to improve students' understanding of biology content. They are not designed to improve students' science process skills. Approximately one hour and 30 minutes is required to complete both programs (45 minutes/program).

The students in the treatment group completed the first two programs in the CAI module; Science Skills I and Investigating Photosynthesis. Approximately one hour and 30 minutes is required to complete both programs (45 minutes/program).

Both the treatment and control group worked simultaneously in the same classroom. The classroom contained 30 IBM-compatible microcomputers, equipped with video graphics array (VGA) adapters and color monitors. The students worked individually at separate computers. The instructor was in the classroom throughout the lesson, but did not provide any instruction other than answering questions concerning computer operation.

The students participating in the experiment had prior experience with computers and computer tutorials. All the students were familiar with the basic operation of microcomputers.

One week later, during the second laboratory meeting, the control group completed the tutorials; Chemicals of Life III: Proteins and Nucleic Acids ("Chemicals of Life III," 1986), and Modern Genetics: Chromosomes and Coding ("Modern Genetics," 1986). These commercially produced tutorials use text and animated graphics to introduce students to basic cell biology concepts. The programs are not designed to improve students' science process skills. Approximately one hour and 30 minutes is required to complete both programs (45 minutes/program).

During this session, the treatment group completed the last two programs in the CAI module; The Effect of pH on Enzyme Action, and Science Skills II. These programs require about one hour and 30 minutes to complete (45 minutes/program). After all the students had finished their work, the TIPS II (Burns, et al., 1985) was administered to the section as the posttest.

Data Analysis

Null hypotheses 1 and 2 were tested with a one-way analysis of covariance. Treatment (group) was the independent variable. Posttest scores were the dependent variable. Pretest scores were used as a covariant to control for initial differences. This statistic was used to determine if the independent variable produced a statistically significant (α=0.05) difference between the mean gain scores of the two groups on the TIPS and TIPS II subtests.

Null hypotheses 3 and 4 were tested with a two-way (gender and academic aptitude) analysis of covariance. Gender and academic aptitude were the independent variables. Posttest scores were the dependent variable. Pretest scores were used as a covariant to control for initial differences. This statistic was used to determine if the independent variables (gender and academic aptitude) produced a statistically significant (α=0.05) difference between the mean gain scores of the two groups on the TIPS II. Since these hypotheses involved only students who had completed the CAI module, the control group could not be included in the analysis.

RESULTS AND DISCUSSION

The purpose of this study was to develop a CAI module designed to improve the integrated science process skills of community college students and to determine the effect of the program on the students' integrated science process skills. Students were randomly placed into treatment and control groups. The students were administered the TIPS as a pretest. The members of the treatment group received instruction from a CAI module designed to improve integrated science process skills. The control group did not receive any instruction related to science process skills. Instead, the control group received instruction from a group of computer programs on cell chemistry. Following instruction, the TIPS II was administered to both groups as a posttest. Table 3 contains the mean scores for each of the tests.

Table 3

Mean Test Scores

Test	*M* Composite Score	*M* Subtest Scores 1[c]	2[d]	3[e]	4[f]	5[g]
Control						
Pretest[a]	22.6	6.9	5.7	4.2	2.1	3.7
Posttest[b]	23.2	7.6	5.8	3.6	2.2	4.0
Treatment						
Pretest[a]	24.2	7.3	6.3	4.7	2.1	3.8
Posttest[b]	26.1	8.4	6.4	4.4	2.3	4.6

Note. [a]TIPS, [b]TIPS II, [c]Identifying Variables, [d]Identifying and Stating Hypotheses, [e]Operationally Defining, [f]Designing Investigations, [g]Graphing and Interpreting Data.

Null Hypothesis 1

There will be no significant difference ($\alpha=0.05$) between the mean gain in integrated science process skills of those students who participate in the computer module and those students who do not participate in the computer module as measured by the students' total score on the TIPS. Table 4 contains the results of the analysis of covariance by group. Pretest scores were used as the covariate.

Table 4

Analysis of Covariance of Composite Scores for Group

Source of Variation	df	Mean Square	F	p
Group	1	47.93	3.26	0.074
Covariate	1	3547.26	241.30	<0.001

An examination of the analysis of covariance by group (see Table 11) indicates no significant difference ($\alpha=0.05$, $p=0.074$) between the gain scores of the treatment and control groups on the TIPS. Therefore, Null Hypothesis 1 is not rejected.

Null Hypothesis 2

The mean gain scores on the TIPS subtests of students who participate in the computer module will not be significantly different ($\alpha=0.05$) from those of students who do not participate in the computer module. Analysis of covariance was used to analyze the scores. Pretest scores were used as the covariate. Table 5 presents the results for the five subtests.

Table 5

Analyses of Covariance of Subtest Scores for Group

Subtest	Source of Variation	df	Mean Square	F	p
1[a]	Group	1	10.30	1.85	0.18
	Covariate	1	191.86	34.50	<0.001
2[b]	Group	1	1.13	0.46	0.50
	Covariate	1	219.60	89.33	<0.001
3[c]	Group	1	3.08	1.50	0.22
	Covariate	1	86.43	41.98	<0.001
4[d]	Group	1	0.14	0.22	0.64
	Covariate	1	18.23	29.73	<0.001
5[e]	Group	1	6.66	4.90	0.03
	Covariate	1	51.06	37.60	<0.001

Note. [a]Identifying Variables, [b]Identifying and Stating Hypotheses, [c]Operationally Defining, [d]Designing Investigations, [e]Graphing and Interpreting Data.

An examination of the analysis of covariance by group (see Table 5) indicates that for subtests 1 through 4 there was no significant difference ($\alpha=0.05$) between the gain scores of the treatment and control groups. However, an examination of the analysis of covariance by group (see Table 5) and the adjusted means on subtest 5 (see Table 6) indicates that the gain scores of students in the treatment group were significantly higher (α=0.05, p=0.03) than those in the control group. Null Hypothesis 2 should therefore be rejected.

Table 6

Means for Subtest 5 (Graphing and Interpreting Data) by Group

Group	Pretest Mean	Posttest Mean	Adjusted Posttest Mean	N
Treatment	3.8	4.6	4.6	46
Control	3.7	4.0	4.0	46

Null Hypothesis 3

There will be no significant difference (α=0.05) between the TIPS mean gain scores of low and high academic aptitude students, as determined by the American College Testing Program Assessment (ACT), following instruction with the computer module. Students were classified as low or high academic aptitude based on their composite ACT score. A student with an ACT score equal to, or greater than, the mean score for the entire sample was classified as having high academic aptitude. A student with a composite ACT score less than the mean for the entire sample was classified as having low academic aptitude. The mean composite ACT score was 18.9

for the entire sample. Forty-nine students were classified as high academic aptitude. Forty-three students were classified as low academic aptitude.

Table 7 contains the results of the analysis of covariance for the independent variables gender and academic aptitude. Pretest scores were used as the covariate. Only the scores of the treatment group were used in this analysis.

Table 7

Analysis of Covariance for Gender and Academic Aptitude

Source of Variation	*df*	Mean Square	*F*	*p*
Gender	1	0.28	0.02	0.89
Aptitude	1	31.87	2.08	0.16
Gender X Aptitude	1	3.07	0.20	0.66
Covariate	1	707.66	46.08	<0.001

An examination of the analysis of covariance by academic aptitude (see Table 7) indicates no significant difference ($\alpha=0.05$, $p=0.16$) between the gain scores of high academic aptitude students and low academic aptitude students. Therefore, Null Hypothesis 3 should not be rejected.

Null Hypothesis 4

There will be no significant difference (α=0.05) between the mean gain scores of males and females on the TIPS following instruction with the computer module. The treatment group contained 17 male students and 29 female students. An inspection of the analysis of covariance by gender (see Table 7) indicates no significant difference (α=0.05, *p*=0.89) between the gain scores of male students and female students. Therefore, Null Hypothesis 4 was not rejected. No significant (α=0.05, *p*=0.66) gender by academic aptitude interactions were indicated.

Conclusions

There was no significant difference (α=0.05, *p*=0.07) between the mean gain in integrated science process skills of those students who participated in the computer module and those students who did not participate in the computer module as measured by the students' total score on the TIPS. The adjusted posttest mean for the treatment group was 25.4. The control group had an adjusted posttest mean of 24.0. This finding suggests that the CAI module was not effective in significantly improving the integrated science process skills of the students.

Care must be taken in generalizing the results of this experiment to other instructional situations. It is reasonable to expect the effectiveness of CAI to be very dependent on the instructional software used. Likewise, it is likely that the amount of time allotted to CAI could influence the effectiveness of CAI. These factors should be considered when comparing this study to other studies on the effectiveness of CAI. However, the results of this study do strongly suggest that instructional software, similar in design to that used in this study, will not produce significant (α=0.05) improvements in students' overall integrated science process skills after only 3.5 hours of instruction.

In contrast, Faryniarz and Lockwood (1992) found that community college students who completed a self-instructional module, containing three computer simulations, gained significantly (α=0.05) more on the TIPS II posttest than students who did not complete the module.

Rivers and Vockell (1987) reported the results of three studies that investigated the effect of CAI on the problem-solving ability of high school biology students. In two of the described studies, CAI produced significant (α=0.05) gains in students' posttest scores. In one of the reported studies, no significant (α=0.05) gain was detected. The authors suggested that the discrepancy was due to differences in the structure and content of the courses involved in the study. The discrepancy between the results of the present study and the work of Faryniarz and Lockwood (1992) and Rivers and Vockell (1987) could have been produced by a number of factors including differences in the instructional software and time spent on CAI.

The gain scores of students in the treatment group were significantly higher ($\alpha=0.05$, $p=0.03$) on TIPS subtest 5, Graphing and Interpreting Data, than those of students in the control group. This finding indicates that the CAI module can be used to effectively improve students' graphing and data interpretation skills. This finding is similar to that of Faryniarz and Lockwood (1992) who found that the scores of community college biology students increased significantly on subtests 4 (Designing Investigations) and subtest 5 (Graphing and Interpreting Data) following CAI. Although the students' scores improved on the other subtests, Faryniarz and Lockwood did not find significant differences for the other three subtests. It is possible that the nature of graphing skills makes them especially suitable for CAI. It is also possible that graphing skills are simply easier to teach, with any methodology, than the other integrated science process skills.

Adams and Shrum (1988) found that computerized data acquisition and graphing had a significant ($\alpha=0.10$) negative effect on students' graph construction skills. However, students' data interpretation skills were improved by computerized data acquisition and graphing.

There was no significant difference ($\alpha=0.05$, $p=0.16$) between the TIPS mean gain scores of low and high academic aptitude students. This finding indicates that the relative effectiveness of the CAI module was not influenced by a student's academic aptitude. Caution should be used in generalizing this finding beyond the circumstances of this study. The sample size used in this study was relatively small ($N=46$). Additionally, different software designs may be more effective with students of different academic aptitudes. Since most educational software presents information as text, it appears possible that students with poor reading comprehension will gain less than students with good reading comprehension. It is reasonable to expect reading comprehension to contribute to a student's academic aptitude. The results of this study suggest that CAI, written at the high school level, can be used with equal effectiveness throughout the range of academic aptitudes normally found in community college students.

There was no significant difference ($\alpha=0.05$, $p=0.89$) between the TIPS mean gain scores of male and female students. This finding indicates that the relative effectiveness of the CAI module was not affected by a student's gender. This finding should be viewed with some caution considering the relatively small sample ($\underline{N}$=46). The results of this study support the findings of Bernardo (1992), Esterling (1992), Fredenber (1994), Land and Haney (1989), Harris (1991), Roblyer (1989), and Tanamai (1990). These studies found no significant link between gender and the effectiveness of CAI.

Implications

The results of this study produce several important implications. First, the failure to reject Null Hypothesis 1 suggests that it is relatively difficult to significantly improve the overall integrated science process skills of community college students. Even though the CAI module was specifically designed to improve integrated science process skills, received good reviews from experienced science educators, and showed promising field test results, it did not produce significant (α=0.05, $\underline{p}$=0.07) gains in students' TIPS posttest scores. It appears that educators should not expect this, or similar software, to produce rapid improvement in their students' overall integrated science process skills. However, the CAI module did significantly (α=0.05, $\underline{p}$=0.03) improve students' ability to graph and interpret data. This indicates that the software does have instructional value and that educators can expect this and similar software to produce significant improvement in students' graphing and data interpretation skills.

This study found that a students' academic aptitude had no significant (α=0.05, p=0.16) effect on the effectiveness of CAI. This finding should be considered with some caution in light of the relatively small sample size (N=46). However, it suggests that the relative effectiveness of CAI is not strongly effected by a student's academic aptitude as measured by their composite ACT score. The results suggest that the relative effectiveness of CAI is similar for students throughout the range of academic aptitudes found in the study sample. This study provides no support for the differential use of CAI based on student academic aptitude as measured by the composite ACT score.

The results of this study suggest that student gender does not significantly (α=0.05, p=0.89) effect the effectiveness of CAI. Because of the relatively small sample size, some caution should be used when considering this finding. However, the findings support those of a number of other studies, (Bernardo, 1992; Esterling, 1992; Fredenber, 1994; Harris, 1991; Land & Haney, 1989; Roblyer, 1989; Tanamai, 1990). It appears that a student's gender does not effect the relative effectiveness of CAI. This study provides no support for the differential use of CAI based on student gender.

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